Diethyl Ether as Additive and its Effect on Diesel Engine Performance – A Review

Sandip S. Jawre
Department of Mechanical Engineering
Jawaharlal Darda Institute of Engineering and Technology Yavatmal, MH, India

Abstract

Increasing demand of fuel day by day its consumption and hazards cause serious intensive attention is required for this problem. Also an Improvement of fuel properties are essential for suppression of pollutant and optimization of engine performance. One way is use of additives. Oxygenated additives were conventionally recommended for gasoline. But now day's oxygenated additives are widely considered for diesel fuel. This additives can also be used in combination with biodiesel. There are number of additives are available for diesel fuel. On the basis of different experimental investigations by the researchers ,this paper reviews about Di-ethyl Ether (DEE) as oxygenated additives mixed with diesel- biodiesel blends and compares its effect on performance and exhaust gas emission of compression ignition engine.

Keywords- DEE, Brake Thermal Efficiency, Oxygenated additives

I. INTRODUCTION

The rapid urbanization, increased vehicular population and the decreasing availability of the fossil fuels have created awareness for effective utilization of the available fuel. Although CI engines have a higher thermal efficiency when compared with SI engine, advanced research in the combustion of diesel fuel in CI engine shows that the Brake thermal efficiency, Brake power can further be increased by allowing the fuel to combine with more oxygen atoms to form complete combustion, this also reduces the smoke, CO and HC emissions. The oxygen composition in the combustion chamber can be increased by adding oxygenates in the diesel fuel. Oxygenates like ethanol, 1-propanol, 1-butanol, 1-pentanol, 2-methoxyethanol, 2-ethoxyethanol, 2-butoxyethanol dibutyl ether and methanol are widely used. Ethanol is used in SI engines to improve the combustion, it has a higher octane value, but for CI engine ethanol has poor cetane value, so it is not possible to use in CI engines. When Ethanol is dehydrated diethyl ether is obtained which has a cetane number of 125 which is very good as a fuel [1]. DEE is liquid at ambient temperature which make it attractive fuel for handling. Various properties of Diesel, Biodiesel and Diethyl ether are given in Table 1.

Table 1: Properties of Diesel, Biodiesel and Diethyl ether

Properties	*Diesel*	*Biodiesel*	*DEE*
Density (Kg/m3)	*823*	*850*	*713*
Calorific value (MJ/Kg)	*43000*	*40800*	*36840*
Viscosity @40°C (cst)	*3.9*	*9.2*	*0.23*
Cetane number	*48*	*42-48*	*125*
Auto ignition temperature °C	*315*		*160*
Oxygen content %	*0*	*11*	*21.6*
Flash point	*56*	*140*	*-40*
Boiling point	*188*		*34*

II. LITERATURE SURVEY

M. Pugazhvadivu et. al. Investigates performance a diesel engine fuelled with biodiesel blends and diethyl ether as an additive [2]. With B25 blend, the NOX emission was reduced by the addition of DEE at all load conditions. With B50, B75 and B100 blends, the NOXemission was lowered by the addition of DEE at low and medium loads. However, at high loads the NOX emission was higher relative to diesel; but lower compared to the corresponding fuel blend. The addition of 15% to 20% DEE was more beneficial in reducing NOX compared to 10% DEE the biodiesel blends tested showed a significant reduction in smoke emission. Further improvement in smoke emission was obtained by the addition of DEE. The addition of DEE resulted in a marginal deterioration of thermal efficiency. It is concluded that the addition of 15%-20% DEE to biodiesel blends would result in reduction of both NOX and smoke emission.

S.K. Mahla et al. Studied The Performance Characteristics Of Acetylene Gas In Dual Fuel Engine With Diethyl Ether Blends[3]. Experiments were conducted to study the performance characteristics of DI diesel engine in dual fuel

mode by aspirating Acetylene gas in the inlet manifold, with diesel- diethyl ether blends (DEE) as an ignition source. Fixed quantity of Acetylene gas was aspirated and Blend of diethyl ether with diesel (DEE10, DEE20 and DEE30) was taken and then readings were taken at various loads. From the detailed study it has been concluded that the blending ratio of DEE20 gives better performance. Dual fuel operation along with addition of diethyl ether resulted in higher thermal efficiency when compared to neat diesel operation. Acetylene aspiration reduces smoke and exhaust temperature.

Thamaraikannan M. et al. Carried an experimental analysis of Combustion and Emissions characteristics of CI Engine Powered with Diethyl Ether blended Diesel asFuel[4]. Experiments were carried out with 5% DEE and 10 % DEE blend. When the DEE composition was further increased beyond 10% the engine became unstable and heavier smoke were observed. This may be due to the phase separation of the blend, which results in cavitation in the injector nozzle and it leads to poor injection of fuel in to the combustion chamber. Blending DEE with diesel and its usage in conventional diesel engine increases the brake thermal efficiency and reduces the BSFC. The NOx emissions are reduced and there is an increase in the CO and HC emission this can be avoided if optimum DEE and Diesel fuel blending ratio is used without making the fuel mixture to be too lean. The high latent heat of evaporation of DEE counter acts the cetane benefit which increases the HC emission.

Y. V. V. SATYANARAYANAMURTHY investigate effects of real time secondary co-injection of water – diethyl ether solution in diesel engine fuelled with palm kernel methyl ester[5] At Full load running of the engine the Specific fuel consumption for the flow rate of 15% vol. Water-DEE solution coincided with that of injection, indicating that the mass flow rate of 5% vol. Water-DEE solution (thresh hold percentage) in the duel fuel operation is beneficial in view of other advantages from the exhaust pollution angle especially in the case on 'NO' emission. Exhaust gas temperatures at all loads in the case of 15% vol. Water-DEE solution injection are almost equal to the temperatures emitted during neat diesel operation. There is a straight reduction of approximately 500 ppm in NO level when the flow rate of saturated water-DEE solution is increased from 5% vol. to 15% vol. Water-DEE solution. The emission of HC with the injection of saturated 15% vol. Water-DEE solution is closely tallying and proximate to the neat diesel operation.

Akshatha D.S et al. evaluate performance of neem biodiesel on CI engine with diethyl ether as additive [6] The fuel blends investigated for performance analysis are 100% diesel (B00), blend of 20% biodiesel and 80% diesel (B20), blend of 40% biodiesel and 60% diesel (B40) and further 10%, 15% Di ethyl ether is added to the blends and results were compared. The BTE of Neem blends were lower than with diesel throughout the entire range showing the poor combustion characteristics of methyl ester due to high viscosity and poor volatility. When the injection pressure is increased to 250 bar the better mixing and proper utilization of air converted more heat into the useful work resulting in higher BTE of around 3.5%, with further increase in pressure to 290 bars, BTE tends to decrease. The emissions of hydrocarbons (HC), carbon monoxide (CO) are considerably reduced for all biodiesel and additive blends, as injection pressure is increased the emissions goes on decreasing due to complete combustion of fuels.

M.V.Mallikarjun identify the potential of blending DEE with diesel transportation fuel [7]. Engine tests were conducted with 5% 10 %, 15% and 20% DEE/Diesel blends. The nitrogen oxide (NOX) emissions are high and it is necessary to reduce this emission before using methyl ester as a fuel for diesel engines. In the present work, retardation of injection timing and exhaust gas recirculation (EGR) are used to reduce the same. However UBHC, CO and particulate emissions increase when retarding the injection timing. But these pollutants are low compared to normal diesel operation. Injection timing of 20.9^0CA bTDC is found to give optimum results. The adopted concept of exhaust gas recirculation showed considerable reduction in nitrous oxides and slight improvement in BTE for 10% of EGR when the engine is operated at an optimal blend. Further diethyl ether is used as an additive and engine emissions particularly NOx found to be at reasonable level for 10% of DEE addition but not compromising in thermal efficiency and specific fuel consumption.

Rizalman Mamat et al investigates Effects of Diethyl Ether Additives on Palm Biodiesel Fuel Characteristics and Low Temperature Flow Properties [8]. In this study an oxygenated additive diethyl ether (DEE) was blended with palm oil biodiesel (POME) in the ratios of 2%, 4%, 6% and 8% and tested for their properties improvement. These blends were tested for energy content and various fuel properties according to ASTM standards. Qualifying of the effect of additive on palm biodiesel fuel properties can serve the researchers who work on biodiesel fuels to indicate the fuel suitability for diesel engines according to fuel standards. Blends of DEE in POME resulted in an improvement in acid value, viscosity, density and pour point with increasing content of DEE, accompanied by a slight decrease in energy content of biodiesel.

Gaddale Amba Prasad RAO et al. [9] carried experimental evaluation of a single cylinder water-cooled diesel engine by adopting various proportions of ethanol and di ethyl ether blends in order to improve performance and emission characteristics of B20 blend. Besides employing different amounts of ethanol and di ethyl ether, simultaneous influence of injector nozzle whole size and fuel injection pressure are also investigated to arrive at an optimum configuration. Brake specific fuel consumption and hydrocarbon emissions values are lower with B20 and DEE 5 whereas B20 with DEE15 yielded lower NOx emissions. It is observed that addition of oxygenates have improved the combustion process and lower emissions are obtained. The present investigation revealed that blends with oxygenated additives having higher cetane rating are superior to neat blend.

Masoud Iranmanesh Investigate Effect of New Combination of Biofuels on Simultaneous Reduction Of NOx and Smoke Emissions in DI-Diesel Engine [10]. In this study, various percentage of DEE was added to the optimum selected ethanol-diesel blend (D-E10) and optimized its blending ratio to overcome the poor ignition quality of ethanol when utilized in a single cylinder DI diesel engine. Results have shown that addition of biofuels, ethanol and diethyl ether, have improved the combustion and emissions characteristics of the engine. Addition of ethanol and DEE improved smoke and NOx emissions simultaneously. It was found the 8% DEE add to the D-E10 blend is the optimum combination based on the performance and emission analysis with the

exception of smoke opacity in which 15% DEE addition made the lowest smoke opacity. At this optimum ratio the minimum peak heat release rate, the lowest NOx emissions and the maximum BTE were occurred at full load condition. Meanwhile the lowest level of CO and HC emissions were obtained at all the load conditions with the same blending ratio.

D. D .Nagdeote et al. [11] An experimental investigation is conducted to evaluate the effects of using diethyl ether and ethanol as additives to biodiesel/diesel blends on the performance and emissions of a direct injection diesel engine. The test fuels are denoted as DI (100%diesel) ,BD (20% biodiesel and 80% diesel in vol.), BDET (15% biodiesel, 80% diesel , and 5% diethyl ether in vol.) and BDE (15% biodiesel ,80% diesel and 5% ethanol, in vol.) respectively. The results indicate that, compared with BD, there is slightly lower brake specific fuel consumption (BSFC) for BDET. Drastic reduction in smoke is observed with BDET and BDE at higher engine loads. BDET reflects better engine performance and combustion characteristics than BDE and BD.

N.K. Miller Jothi et al. studies Experiment on homogeneous charge CI engine fueled with LPG using DEE as an ignition enhancer [12]. It is possible to operate the DI compression ignition engine smoothly with stable combustion on neat LPG over the entire range of loads by the introduction of 58% to 28.8% of DEE on mass basis. Brake thermal efficiency in LPG mode is lower by about 23% at full load than the diesel operation as a result of increased vaporization of DEE that cools the intake charge, thereby reducing the cylinder gas temperature.

Dr. V. Rambabu [13] performance and combustion characteristics of di-diesel engine using neat MME with DEE. 15% DEE blend with biodiesel is adjudged as the best combination which yielded better results than other fuel blends tested especially 3% blend which is the nearest competitor. 3% and 15% blends create delay period difference of 0.4 ms (lesser for 15% blend) which can be observed from the real time, time wave plots at full load. But in the case of 15% blend, the diffused combustion aspect is very much improved. The thermal efficiency rise and SFC are better in the case of 15% additive blend and since diesel engines give better efficiency at part loads this percentage of blend can be recommended. The smoke levels have decreased substantially with 15% DEE blend with biodiesel at full load and at immediate part load except very low loads at which the diesel engine may not be put to operation normally because of high bsfc. Smoke levels have decreased in ta dem indicating better combustion.

III. RESULTS AND DISCUSSION

A. Total Fuel Consumption

With the increase in load the amount of fuel required to produce the necessary brake power increases and with the increase in the addition of the DEE the total fuel reduces more in the low load conditions and it is almost the same at peak load conditions. DEE being an oxygenate increases the combustion efficiency and makes an effective utilization of the fuel, converting CO and HC into CO2and H2O. Brake Specific Fuel Consumption: The BSFC is higher for lower loads and it decreases in the mid loads and remains the same for peak loads. The BSFC is lower for 10 % DEE blend. This is due to better combustion of diesel fuel, which results in higher heat release. The cylinder pressure of 10% DEE was higher than other blends and diesel. This increase in cylinder pressure results in higher power output. Hence, there is a considerable saving in the fuel. When the DEE composition is further increased, due to decrease in the calorific value of the fuel the BSFC increases.

B. Brake Thermal Efficiency

The results of engine thermal efficiency using different biodiesel blends are given in Fig. With all the biodiesel blends, the thermal efficiency decreased marginally compared to diesel due to the lower heating value of biodiesel [2]. Addition of 20% DEE to biodiesel blends, the results indicate that the addition of DEE decrease the thermal efficiency marginally due to the lower heating value of DEE. The increase in brake power with reduced fuel consumption at higher loads helps to increase the BTE at higher loads [4]. With the reduction in the fuel consumption and the effective burning of HC in the fuel the heat energy is obtained at its maximum from the fuel. The presence of oxygen in the DEE blend helps in complete combustion of the fuel raising the BTE.

C. Brake Specific Fuel Consumption

The BSFC is higher for lower loads and it decreases in the mid loads and remains the same for peak loads[4]. The BSFC is lower for 10 % Dee blend. This is due to better combustion of diesel fuel, which results in higher heat release. The cylinder pressure of 10% DEE was higher than other blends and diesel. This increase in cylinder pressure results in higher power output. Hence, there is a considerable saving in the fuel. When the DEE composition is further increased, due to decrease in the calorific value of the fuel the BSFC increases.

D. NOx Emission

The NOx concentration varies linearly with the load of the engine. As the load increases, the overall fuel-air ratio increases, resulting in an increase in the average gas temperature in the combustion chamber, and hence NOx formation, which is sensitive to temperature increase[7]. At all loads the emission NOx for 20% MIME is found to be maximum because all vegetable oils are oxygenated intrinsically. When small quantities of additives like DEE is started adding the NOx content started reducing. Among the different cases of diethyl ether lower NOx levels were observed with DEE15 additive [9]. The NOx emissions

are plotted for the full load power. Since the diesel engine combustion experiences high in-cylinder temperatures in 75-100% of the full load power.

E. HC Emission

At full load HC emission in the exhaust has decreased with the increased volume of water-DEE solution[5]. At full load there is a straight decrease of 30 ppm with increase of water-DEE solution from 5% to 25%.The rise in HC is Maximum to the tune of 110 ppm at 15% vol. Water-DEE solution at Zero load on the engine this is due to the charge dilution because of low combustion temperatures. Therefore no load running of the engine is not suggested. Neat biodiesel PKME operation at all loads emitted least amounts of HC when compared to all aspects of duel fuel operation.

F. Carbon Monoxide Emission

CO concentration in the exhaust Emission is negligibly small when a homogeneous mixture is burned at stoichiometric air-fuel ratio mixture or on the lean side stoichiometric. With increasing DEE percentage in the blend, CO emission level is decreased for 5% DEE and thereby increases up to 20% DEE due to poor combustion[8].

G. The Smoke Opacity

Lowest Values for Smoke Are observed for the case of B20 with DEE5 and highest being B20. Since the unburned HC emissions are lower with DEE5 case, smoke opacity values are also lower for the same combination [9]. Improved and complete combustion could be the reasons for obtaining lower smoke opacity values with oxygenated additives. Therefore, it can be concluded here that DEE has proven to be eco-friendly additive to improve the performance and emissions of B20 blend.

CONCLUSION

Salient features of the conclusions that were obtained from comparison of experimental investigations by authors using various DEE blends are as follows.

DEE can be successfully added to the optimum selected E-Diesel blend and optimized its blending ratio to overcome the poor ignition quality of ethanol.

Some physicochemical properties of D-E10 blend such as ignition quality, boiling point, oxygen content and distillation profile were improved by addition of DEE.

It can also act as a powerful co-solvent when add to E-Diesel blend. Front-end volatility of the blends also improved, which in turn improved the cold starting property. The heating value, density and viscosity of the blends reduced with addition of DEE.

The addition of diethyl ether with biodiesel reduces the exhaust emissions well. The present results from literature support that use of DEE as an additive with biodiesel improve the performance and reduce the NOx.

REFERENCES

[1] Brent Bailey, Jimell Erwin "Di ethyl Ether as renewable diesel fuel" National Renewable Energy Laboratory.
[2] M. Pugazhvadivu and S. Rajagopan "Investigations on a diesel engine fuelled with biodiesel blends and diethyl ether as an additive" Indian Journal of Science and Technology (May 2009) Vol.2 No 5.
[3] S.K. Mahla, Som Kumar, Harshdeep Shergill "Study The Performance Characteristics Of Acetylene Gas In Dual Fuel Engine With Diethyl Ether Blends" International Journal on Emerging Technologies(2012) vol. 3 no.1
[4] Saravanan D. , Vijayakumar T. and Thamaraikannan M , "Experimental analysis of Combustion and Emissions characteristics of CI Engine Powered with Diethyl Ether blended Diesel as Fuel", Research Journal of Engineering Sciences (2012); Vol. 1(4), 41-47.
[5] Y. V. V. SATYANARAYANAMURTHY, "experimental investigations of real time secondary co-injection of water – diethyl ether solution in di-diesel engine fuelled with palm kernel methyl ester" Journal of Engineering Science and Technology (2012) Vol. 7, No. 6 711 – 721
[6] Akshatha D. , Manavendra. , S.Kumarappa Performance evaluation of neem biodiesel on ci engine with diethyl ether as additive International Journal of Innovative Research in Science, Engineering and Technology, 2013; Vol. 2(8) , 2319-8753.
[7] M.V.Mallikarjun, Venkata Ramesh Mamilla, G. Lakshmi Narayana Rao "NOX emission control techniques when CI engine is fuelled with blends of mahua methyle esters and diesel" International Journal of Engineering Sciences & Emerging Technologies, 2013. Volume 4, Issue 2, pp: 96-104.
[8] Obed M. Ali, Rizalman Mamat, "Effects of Diethyl Ether Additives on Palm Biodiesel Fuel Characteristics and Low Temperature Flow Properties", International Journal of Advanced Science and Technology (2013); Vol. 52.
[9] Prasad. U.S.V., Madhu Murthy. K., And Amba Prasad Rao. G. , "Effect of Oxygenated Additives on Control of Emissions in a DI Diesel Engine using Biodiesel-Diesel Blends" International Conference on Mechanical, Automobile and Robotics Engineering (2012).
[10] Masoud Iranmanesh, "Experimental Investigations about the Effect of New Combination of Biofuels on Simultaneous Reduction Of NOx and Smoke Emissions in DI-Diesel Engine", International Journal of Automotive Engineering (2013); Vol. 3, No. 2
[11] D. D .Nagdeote, M. M. Deshmukh, "Experimental Study of Diethyl Ether and Ethanol Additives with Biodiesel-Diesel Blended Fuel Engine", International Journal of Emerging Technology and Advanced Engineering, 2012; Volume 2(3), 2250-2459.
[12] N.K. Miller Jothi, G. Nagarajan, S. Renganarayanan, "Experimental studies on homogeneous charge CI engine fueled with LPG using DEE as an ignition enhancer", Renewable Energy, 2007; Vol. 32, 1581–1593.
[13] P. Ramesh Babu, Dr. V. Rambabu, S. Ravi Babu "Performance and combustion characteristics of di-diesel engine using neat MME with DEE" 2013 Volume 3,Issue 3, pages 153-159.